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Original Article

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Effects of Action Observation Training Combied with Auditory Cueing on Gait Ability in Patients with Stroke: a Preliminary Pilot Study

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Purpose: New therapeutic approaches have emerged to improve gait ability in patients with brain damage, such as action observation learning (AOT), auditory cueing, motor imagery etc. We attempted to investigate the effects of AOT with auditory cueing (AOTAC) on gait function in patients with stroke.

Methods: The eighteen stroke patients with a unilateral hemiparesis were randomly divided into three groups; the AOTAC, AOT, and control groups. The AOTAC group (n = 8) received training via observing a video that showed normal gait with sound of footsteps as an auditory cue; the AOT group (n = 6) receive action observation without auditory stimulation; the control group (n = 5) observed the landscape video image. Intervention time of three groups was 30 minutes per day, five times a week, for four weeks. Gait parameters, such as cadence, velocity, stride length, stance phase, and swing phase were collected in all patients before and after each training session.

Results: Significant differences were observed among the three groups with respect to the parameters, such as cadence, velocity, stride length, and stance/swing phase. Post-hoc analysis indicated that the AOTAC group had a greater significant change in all of parameters, compared with the AOT and control groups.

Conclusion: Our findings suggest that AOTAC may be an effective therapeutic approach to improve gait symmetry and function in patients with stroke. We believe that this effect is attributable to the change of cortical excitability on motor related to cortical areas.

Keywords: Action observation learning, Gait ability, Stroke

INTRODUCTION

Stroke is generally known to cause motor insufficiency in terms of muscle weakness, spasticity, poor muscle coordination, and abnormal proprioception, which ultimately leads to walking disability.[1-3] The conventional approaches to improve gait function of stroke patients focused on reducing abnormal movement in the affected limb.[4] Recently, with rehabilitative technology developed, new therapeutic methods have been applied in stroke rehabilitation, including robot-assisted therapy, virtual reality-based rehabilitation, and task-specific training.[5-7] However, these did not always obtain the desired goal of both clinicians and patients. Therefore, new therapeutic treatments have been introduced to change the neural structure and function of the brain through stimulating neural cells in the brain, such as action observation training (AOT), motor imagery training, and transcranial direct current stimulation.[8-10]

AOT is one of the motor learning methods for the purpose of acquiring motor skills by observing normal behavior of someone else. It is known to contribute to the function of the mirror neuron system, which leads to the activation of the cortical neurons related to motor execution.[11-13] Several previous studies suggested that the mirror neuron played an important role in eliciting motor cortical activation and facilitating brain recovery in patients with stroke,[14-16] and provided evidences that AOT leads to re-organizational of the brain which is associated with motor learning cortex as the actual motor performance.[4,17] Meanwhile, according to previous literatures, rhythmical acoustic cuing, such as beat music or metronomes, are widespread used for gait rehabilitation in patients with Parkinsonism or

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stroke.[18-20] The acoustic stimulation leads to symmetrical movement by providing a rhythmic cueing through music elements of tempo and beats to improve the asymmetrical gait pattern in stroke patients.[19-21] It has been established that the auditory stimulation with regular rhythm would provide sensorimotor cortical areas with motivation and activation.

Previous studies have shown the effects of action observation or auditory stimulation training to improve balance and gait in patients with stroke.[4,8,12,20] However, the best of our knowledge, little is known about the potential therapeutic approaches simultaneously combined with AOT and auditory stimulation. Therefore, the purpose of this study was to examine whether action observation training with acoustic cueing (AOTAC) could improve walking ability in stroke patients.

METHODS

1. Subjects

The participants in our pilot study were adult stroke patients receiving inpatient treatment for functional recovery at "○○Rehabilitation Hospital" in Daejeon city. Eighteen hospitalized stroke patients were recruited in this study. Prior to participation, all patients fully understood the purpose of the study and were asked to sign a written informed consent statement, which was in accordance with the ethical standards of the Declaration of Helsinki. The protocol for this study was approved by the local ethics committee (041107-201712-HR-005-01). The inclusion criteria were as follows; 1) more than six months since the onset of stroke, 2) no impairment of cognitive function (over 24 points with mini-mental status examination), 3) normal vision and hearing function, 4) no orthopedic impairments on both lower extremity, and 5) independent walking ability over 10m. Demographic data of the patients and normal subjects are summarized in Table 1.

The stroke with a unilateral hemiparesis were randomly divided into three groups: the AOTAC, AOT, and control group. We asked patients in the AOTAC group to watch a video observing normal gait and to listen auditory cues. The patients in the AOT group only watched a video of normal gait, without auditory cues. The control group watched a video of landscape images not related to gait. During the training period, the subjects watched a video composed of a functional gait task through a personal computer monitor in a comfortable sitting position in a quiet room. Participants underwent training for 30 minutes per day, five times a week, for four weeks. The outcome measurements of gait function were conducted before and after the 4-week training. All subjects were given conventional physical therapy treatment 30 minutes per day, five times a week, for four weeks. According to the needs of each subject, additional therapy was performed (e.g., occupational therapy, speech therapy, medial drug therapy, and others). Gait parameters, such as cadence, velocity, stride length, stance phase, and swing phase were collected in all patients before and after each training session.

2. Measurement

Gait analysis, which represented the cadence, velocity, stride length, stance phase, and swing phase, was measured by using the G-walk AP1177 system (BTS G-WALK, BTS Bioengineering Corp., Quincy, MA, USA). The G-walk is a wireless analysis system which consists of, triaxial accelerometer, magnetic sensor, and triaxial gyroscope. The wireless triaxial accelerometer is equipped with a Bluetooth sensor and is attached to the 5th lumbar vertebra of subject using a strap belt. The signs of G-sensor with Bluetooth sensor are transmitted to a personal computer with a BTS G-studio software. The BTS G-studio software program analyzes the parameters of gait function, which collected during walking. The subjects were asked to walk 10-meter distance as fast as they could. The measurement of gait parameters was started when the first foot contacted on the ground, and was finished when the last foot was passed over the finish line.

Table 1. General characteristics of subjects

	AOTCA	AOT	Control group	p
Gender (M/F)	5/3	4/2	3/2	
Age (yr)	59.8±8.2	58.5±15.1	56.2±10.5	0.689
Height (cm)	162.5±7.9	166.6±11.8	163.2±6.5	0.727
Weight (kg)	60.0±7.5	62.8±10.2	66.6±2.3	0.697
Onset time (month)	45.88±23.67	44.17±21.40	43.80±26.63	0.981
MMSE-K (score)	25.88±1.96	26.17±2.48	27.60±3.28	0.593
Stroke type (infarction/hemorrhage)	6/2	4/2	4/1	
Hemiplegic side (right/left)	4/4	4/2	3/2	

Mean±SD.
AOTCA: Action observation training with acoustic cueing, AOT: observation training.

3. Training procedure

1) AOTAC group

The contents of action observation training consisted of gait performance that they experienced in the premorbid level, including flatland walking (straight walking, walking with head turned to left and right, and side walking), obstacle walking (walking over obstacles, turn the obstacle clockwise, turn the obstacle counterclockwise), and stair walking (up stair and down stair) task.

All aspects of the action observation consisted of two walking speed conditions; one was normal speed and another at two times slower than normal speed (using the video player). The subjects observed the video of two walking speed conditions in sequence for five minutes. The action observation order according to walking speed was first at a normal speed, and then observed at a speed twice as slow. In order to observe the three-dimensional walking movement, the observation views of walking performance were provided in the front, back, and side views. The subjects were asked to observe each the walking performance video as carefully as possible during a two walking speed conditions with the supervision of a physical therapist. Then, the subject executed the walking performance in the same video image environment for 10 minutes, immediately after the observation. All subject in the AOTAC group carried out the two sessions for 30 minutes. In addition, the AOTAC group was combined with auditory stimulation during action observation. For auditory stimulation, subjects listened to a heel-clicking sound via earphone through a personal computer when contact the left or right heel, while observed the walking performance. The beat rate of heel-clicking sound was set to match the cadence of patients during comfortable walking speed.

2) AOT group

The AOT group, which was to eliminate auditory stimulation, was observed to equal walking performance contents of action observation for five minutes as the AOTAC group. Then, the subject executed the walking performance in the same video image environment for 10 minutes, and was carried out twice for 30 minutes.

3) Control group

The control group was asked to observe a video composed of a natural landscape with no moving people instead of action observation or auditory stimulation, and was provided the same walking training protocols as the AOTAC and AOT group.

4. Statistical analysis

The statistical analysis was performed using SPSS Version 22.0 (IBM Corp., New York, USA) for Windows. The nonparametric Kruskal-wallis test was performed to compare the significant differences between the AOT with auditory cueing, action observation, and control group in before and after intervention. For post hoc test, the Mann-Whitney test by Bonferroni's method was used to compare the gait parameter of the three groups. A Wilcoxon test was used to compare between the pre- and post-intervention. The level of significance was selected at 0.05 as the p value.

RESULTS

Table 1 indicated the characteristic of the participants. No significant intergroup differences were found with respect to age, height, weight, onset time, or MMSE-K score ($p > 0.05$). Table 2 showed the pre-test and post-test measurements of gait parameter for each group. In the Kruskal-wallis test, it showed significant differences among three groups, in term of cadence, velocity, stride length, stance phase, and swing phase ($p < 0.05$). In the post hoc analyses, it indicated that the AOTAC group showed more significant changes in gait parameter group (cadence, velocity, stride length, stance phase, and swing phase) than in the control group ($p < 0.05$). In addition, gait parameter (cadence, velocity, stance phase, and swing phase) is also significantly different in the AOTAC group, when compared with the AOT group ($p < 0.05$).

DISCUSSION

Our study investigated whether AOTAC could improve gait ability in stroke patients, compared with AOT and control group. Our results revealed that gait ability was improved for both action observations (AOTAC and AOT) after four weeks. However, with respect to the degree of improvement in gait function, the AOTAC group exhibited greater increased spatiotemporal gait function than did AOT group. Therefore, we believed that the AOTAC is an effective therapeutic approach for inducing and enhancing impaired gait function of patients with stroke.

According to many clinical and laboratory studies, it is evident that action observation training has positive effects on motor function in the upper limb,[16,22] as well as postural control.[23,24] Furthermore, walking observation training led to improved spatiotemporal gait function in healthy subjects[25,26] and with neurologic dysfunction, such as Parkinsonism[27,28] and stroke.[24,29] Pak et al.[8] reported that 12 chronic stroke individuals had

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Table 2. Comparison of the G-walking tests in the AOTCA, AOT and Control groups

Variable	Group	AOTCA (n=8)	AOT (n=6)	Control group (n=5)	p
		Mean±SD	Mean±SD	Mean±SD	
Cadence (step/min)	Pre	80.94±19.31	80.19±17.57	77.47±16.39	0.731
	Post	83.94±19.48	80.95±18.06	76.53±15.98	
	Post-Pre	2.99±1.84†‡	0.77±0.61	-0.94±1.12	0.002*
	p	0.018	0.046	0.08	
Velocity (cm/s)	Pre	70.14±18.44	69.33±15.25	67.00±14.51	0.925
	Post	77.43±17.61	71.33±15.54	64.40±14.51	
	Post-Pre	6.87±2.91†‡	2.00±2.00†	2.60±2.51	0.001*
	p	0.017	0.058	0.077	
Stride length (cm)	Pre	73.86±14.37	71.67±18.11	68.80±15.88	0.752
	Post	88.00±13.68	79.17±17.90	69.60±15.73	
	Post-Pre	14.14±6.23†	7.50±4.68†	0.800±3.03	0.03*
	p	0.018	0.028	0.588	
Stance phase (%) (affected side)	Pre	58.44±5.36	55.13±5.37	60.81±5.93	0.464
	Post	61.63±4.29	56.07±5.59	60.15±5.45	
	Post-Pre	3.19±1.79†‡	0.93±0.49	-0.66±1.25	0.004*
	p	0.018	0.028	0.225	
Swing phase (%) (affected side)	Pre	41.56±5.36	44.87±5.37	39.19±5.93	0.464
	Post	38.37±4.29	43.93±5.59	39.85±5.45	
	Post-Pre	-3.19±1.79†‡	-0.93±0.49	0.65±1.25	0.004*
	p	0.018	0.028	0.225	

Mean±SD, AOTCA: Action observation training with acoustic cueing, AOT: Action observation training.
*Significant difference among the groups, †Significant difference in the change values between Control groups ($p<0.05$), ‡Significant difference in the change values between AOT groups ($p<0.05$).

significantly increased gait performance in terms of 10-m walk test, community walk test, activities-specific balance confidence, and spatiotemporal gait parameter, compared with control group who observed the landscape. Unlike single AOT study, AOT combined with treadmill training had been proven as effective method for improvement of the gait function in stroke patients.[30] Function magnetic resonance imaging studies demonstrated that AOT increased brain activity in the premotor and parietal cortex.[31,32] This result meant that action observation training could be subconsciously and directly operated in motor neuron pool taking responsibility for producing substantial movement during observing the action.

Therapeutic approach with rhythmic auditory stimulation is known to be based on the activity that induces stable synchronization between the acoustic cues and motor activity. Several previous studies demonstrated that auditory stimulation using external acoustic cues was beneficial in facilitating rhythmical gait pattern for the purpose of gait rehabilitation.[18,20,33] In particular, Thaut et al.[34] reported that rhythmic auditory cuing led to the improvement in gait and muscular activation pattern, as measured by temporal stride parameters and surface electromyography in terms of stride time, stride length symmetry, and magnitude of muscle activation. There are conversing evidences that acoustic cue can impact gait performance in normal individuals and in patients with neurological dysfunction.

Our results were similar to previous studies, indicating that walking training combined with auditory cueing showed a significant improvement in gait function in terms of TUC, BBS, FMA, and symmetrical step time in stroke patients.[19,20] In addition, Song et al.[35] demonstrated that auditory stimulation with visual stimuli improved balance and gait function after eight weeks of training in patients with Parkinsonism. Consequently, supplemental acoustic cue with the other stimulation or training is an effective therapeutic approach of improving gait function in patients with neurologic disorder. We thought that these positive effectiveness was induced by increased activation of cortical areas related to substantive motor execution, as well as added cuing due to the use of auditory stimulation toward the motor system.

Our results suggested that improvement of gait function is induced by contribution of motor learning due to AOT combined with auditory cueing. The AOTAC could be applied without assistance of therapists or expensive equipment, and to improve gait ability in stroke patients who not learn experience-dependent motor skill due to poor motor function.

Therefore, we thought that auditory cues could be considered along with AOT in stroke patients. Our study has several limitations to consider. First, it is difficult to generalize the findings due to a small sample size. Second, although this study demonstrated improved gait ability after AOT combined with auditory cueing, it did not indicate long term effects of therapeutic approach. We will address these limitations in future studies.

The AOT has been shown to be an effective treatment of individuals with neurologic disorder in previous studies. Our study also indicated that AOT improved gait performance, which was further improved when combined with auditory cues. Therefore, we suggested that additional auditory stimulation during AOT may be an effective therapeutic approach in managing gait performance of stroke patients.

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